Acoustic Scattering from Heterogeneous Rough Seabeds

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LONG-TERM GOALS

The goal of this research is to better understand the physics and mechanisms of sound-seabed interaction, including acoustic penetration, propagation, attenuation and scattering in marine sediments.

OBJECTIVES

The primary scientific objectives of this research are to assess the importance of different mechanisms of scattering and their interactions, such as volume-roughness interaction, with a focus on a discrete scatterers, and to provide physically understandable descriptions at mid- and high-frequencies for near- and sub-critical grazing angles appropriate to the DRI. Also, the research will contribute to modeling and inversions for the ASIAEX program for studying shallow water reverberation.

APPROACH

There are different scattering mechanisms associated with particular types of seabed medium irregularities: volume continuous fluctuations of the sediment acoustic parameters, discrete inclusions (rock, shell hash, etc), roughness of seabed surface and internal interfaces, as well as volume-roughness interactions. In a rigorous and general form, they all can be considered in the frame of a unified approach [1]. A solution for the field in the reference medium, e.g., arbitrarily stratified (plane-layered), is used as a zeroth-order approximation. The unified integral equation provides a relationship of the field perturbations (with respect to the zeroth-order field) and the parameters characterizing the irregularities.

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The DRI environmental data provides the necessary inputs for both reference medium (vertical profiles of the acoustical mean parameters) and irregularities (volume heterogeneity and roughness spatial spectra). Thus, the model of scattering to be developed in this research can be rigorously compared with measured bottom scattering data at the DRI site.

WORK COMPLETED

The analysis of the DRI environmental data has shown some specific features. In particular, the top thin sediment layer has a transition nature, i.e., the acoustical parameters in this layer continuously vary from their values in the water to asymptotic values in the lower half-space. To describe acoustic scattering from such a medium, a new approach has been proposed. It considers a special class of volume perturbations, which exist within stratified media, and describes them in terms of displacement of isosurfaces of these parameters [1,2]. In this case, discrete stratification (layering) is treated as a particular case of continuous stratification, where interfaces between layers are replaced by additional (transition) layers with acoustical parameters smoothly dependent on the depth. In the unperturbed medium, the transition layers are flat, which gives the zeroth-order solution. In the first-order approximation, volume perturbations of the class mentioned above are proportional to vertical gradients of corresponding acoustical parameters in the unperturbed medium and to displacement ("roughness") of the isosurfaces of these parameters within transition layers. Note that there are only smooth continuous volume inhomogeneities in these layers, that is there is no real roughness scattering, which is controlled by discontinuity of the acoustical parameters at the interfaces. A new general model gives the seabed volume scattering strength as a function of the wave thickness of the transition layer, *kh* (see Figure 1). In the limiting case of low frequencies, where the transition layers are thin in comparison with the wavelength, *kh*<<1, the model provides an exact transition to existing results for scattering from rough interfaces.

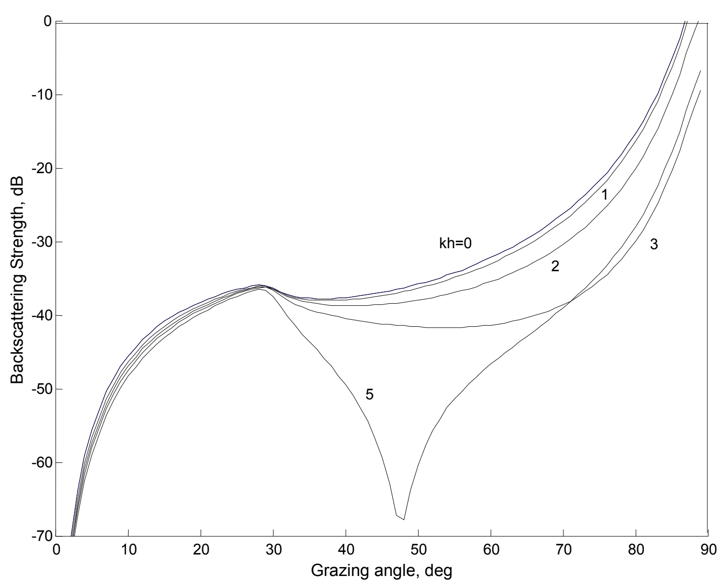

Figure 1. Volume backscattering from sandy bottom as a function of kh (transition layer wave thickness). At kh=0, this approach gives an exact transition from volume to roughness scattering.

Note also that using the low frequency limit, where the transition layer is replaced by a traditional water-sediment interface, and seabed scattering is treated as result of the interface roughness, can create inevitable errors, as the transition layer thickness can vary from site to site resulting in substantial variability in acoustic scattering as well. Quantification of this effect is beyond the traditional approaches. At the same time, a natural consequence of this general model of scattering, where kh is just an input parameter, is that scattering results at larger kh are automatically provided.

RESULTS

A new theoretical model has been developed to describe acoustic scattering from a thin heterogeneous sediment transition layer. In the particular case of low frequencies, where the transition layers are thin in comparison with the wavelength, the model provides an exact transition to existing results for scattering from rough interfaces. At high frequencies, it gives a transition to existing results for scattering from volume heterogeneities. Thus, it naturally links volume and roughness mechanisms of seabed scattering at low and high frequencies within a unified general formalism.

IMPACT/APPLICATIONS

The models of seabed scattering developed in this research will provide a better understanding of bottom acoustic interaction at mid- and high-frequencies and can be used as a basis for improved algorithms for remote acoustic inversions for seafloor properties. The higher fidelity of these models makes them suitable for evaluation of the uncertainty resulting from the simplifications of presently available Navy models.

TRANSITIONS

The results of this work are being adapted in practical models for seabed scattering. For example, a high-frequency bistatic scattering model funded by the ONR Torpedo Environments Program (6.2) incorporates the elastic scattering model developed as part of this work. The correlation method for identifying and/or separating the volume and roughness components of scattering is proposed for application to ASIAEX data and data from other past and future ONR experiments.

RELATED PROJECTS

This research is conducted jointly with the separately funded work of D.R. Jackson and comparisons with CBBL data have been carried out in collaboration with Kevin Briggs, Kevin Williams, Chris Jones and Tim Orsi. The approaches and models developed in this research are relevant to acoustic penetration and multiple scattering issues arising within the ONR Departmental Research Initiative on high-frequency sound interaction with the seafloor.

This research is closely connected to other ONR programs, including the High Frequency Sediment Acoustics DRI, Capturing Uncertainty DRI, and Biological Thin Layers.

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